MALACOLOGIA, 2007, 49(2): 273–281

A FIELD METHOD FOR QUANTIFYING THE GRAZING ACTIVITY OF SLUGS, WITH PARTICULAR REFERENCE TO *ARION LUSITANICUS* (MOLLUSCA)

Alois Honek* & Zdenka Martinkova

Research Institute of Crop Production, Drnovska 507,
CZ-16106 Praha 6 - Ruzyne, Czech Republic

ABSTRACT

In earlier experiments soft, "plasticine" modelling clay was readily consumed by slugs. Therefore, a method for determining the grazing activity of *Arion lusitanicus* using plasticine baits was tested in the field. Plasticine was exposed on the surface of the soil in small trays shielded from mice by wire mesh screens. After several days of exposure, the quantity of plasticine consumed was determined by weighing. Laboratory experiments showed that the amount of plasticine consumed is proportional to slug body mass, plasticine is eaten over a wide range of temperatures between 6–25°C, and the presence of alternative vegetable food does not decrease consumption. In the field, consumption of such baits was positively correlated with slug numbers and revealed variation in slug grazing activity between sites during the course of a season. The use of plasticine baits is recommended for establishing slug feeding activity in the field. This is probably the best method available to date for quantitative studies. Plasticine was also eaten by several other species of slugs and snails.

Key words: baits, plasticine, consumption, temperature, food, grazing, activity, seasonal variation.

INTRODUCTION

Slugs are abundant on agricultural land in Central Europe and consume a variety of food items, including seedlings and mature plants. They become important crop pests, especially when the only plants available are cultivated (Cook et al., 1997; Glen & Moens, 2002; Moens & Glen, 2002). Even in mixed plant stands, they may have a significant effect and completely destroy populations of certain species, particularly seedlings. This is reported for several slug species and plant communities (Bruelheide & Scheidel, 1999; Frank, 2003; Buschmann et al., 2005). Therefore, the determination of slug abundance and activity is important and has been studied by many authors. There are several methods of determining slug abundance. In addition to direct counts and washing slugs from soil samples, various baits and traps are frequently used. That is, slug numbers may be determined, but obtaining precise estimates is laborious.

In a study of invertebrate seed predation (Honek et al., 2003), seeds were presented stuck into the surface of soft plasticine in small tin trays. In the field, the trays were placed in cages made of rectangular wire mesh (9 x 9 mm opening size) that prevented the access of mice, which will eat the plasticine. However, in some places, the plasticine was eaten by slugs to such extent that it was decided to replace soft plasticine by a kind of modelling clay that hardens on exposure to air (Honek et al., 2005). Even large slugs easily passed through wire mesh and were observed consuming the plasticine. The slug damage to the plasticine differed among sites. These difficulties, which made investigating seed consumption impracticable, lead us to the use of baits of soft plasticine to monitor slug grazing activity. In contrast to slug numbers, determining their grazing activity in the field remains unresolved. The consumption of baits of more natural food is not easy to quantify because of its quick deterioration. By contrast, the quantity of

---

*Corresponding author: honek@vurv.cz

plasticine remains unchanged even after long exposure. We therefore tested consumption of this auspicious bait material under a variety of laboratory conditions and in the field.

In our experiments, the grazing activity of *Arion lusitanicus* (Mabille) was investigated. This species was first established in the Czech Republic in 1991 and became widespread between 1996–2000 (Horsak & Dvorak, 2003). Arion lusitanicus is found in dense vegetation, swards, and hedges (Grimm & Paill, 2001). When population outbreaks occur, it colonizes the margins of crops and set-aside fields. It overwinters as an egg. Young animals are found from late April, mature in July–August, and die in October (Briner & Frank, 1998a; Grimm, 2001). In contrast to other slug species (Hommay et al., 1998), it is active during part of the day, until late morning and from early afternoon (Grimm et al., 2000), even on dry, warm and sunny days. *Arion lusitanicus* eats a variety of food, including living herbs, particularly seedlings and may change the species composition of wild herb stands. *Arion lusitanicus* is a serious pest of vegetables and garden plants (Fischer & Reischutz, 1998). The damage to field crops is occasional, limited to years of high abundance and to the margins of fields (Frank, 1998a, b).

This paper reports the results of using baits of soft plasticine for monitoring *A. lusitanicus* grazing activity. The experiments reveal the usefulness of this unnatural material for ecological studies. In particular, the results concerned (i) laboratory experiments to determine the factors that limit the consumption of plasticine and (ii) field experiments to determine the relationship between slug abundance and plasticine consumption, and its local, seasonal, and annual variation. Further laboratory experiments also (iii) determined plasticine consumption of other abundant species of molluscs.

MATERIALS AND METHODS

Presenting Plasticine

Plasticine modelling clay is a non-desiccating and non-solidifying malleable matter consisting of clay (frequently kaolin), oil (rape-seed, vaseline, zinc oleate), wax (bees or Japan), and minor components in various proportions (Barta, 1934). Plasticine used in all the experiments is manufactured by Jovi S. A. (Barcelona, Spain), which is commonly available in art shops. Its precise composition is not available. Pilot experiments have shown that this plasticine does not change in mass when exposed to conditions of 100% relative humidity and 25°C. Average difference after 24 h exposure was only + 0.2 ± 0.4% of the original mass. This plasticine was offered to slugs on tin trays (25 mm diameter, 5 mm deep) in the field, or on plastic trays (10 mm diameter, 3 mm deep) in the laboratory. The plasticine was pressed on to the trays so that its surface was convex. Light plastic trays were used in experiments involving single slugs, because weighing the amounts consumed was more precise. The trays were weighed before exposure to a 10^{-2} g accuracy. After presenting them to slugs, they were cleaned of adhering soil by a gentle flow of water, dried, and weighed. The difference in mass indicated the amount of slug grazing. Records were also made of consumption visually. In all experiments, the trays were replaced before they were completely empty so that the consumption of plasticine per unit time could be calculated.

Experimental Animals

Experiments on *A. lusitanicus* were made at Praha-Ruzyně (50°05'N, 14°15'E, altitude 340 m a.s.l.). Laboratory experiments were made using slugs collected at one place (dense uncut sward in an old pear garden). The slugs were collected randomly, put into a 0.5 l bottle, provided with leaves of herbaceous plants, sprayed with water, and stored at 5°C until the beginning of the experiment, always within 48 h.

Laboratory Experiments

The experimental arena was a plastic cup (8 cm diameter, 4.5 cm high). The bottom of each cup was covered with a 0.5 cm deep layer of field soil, which had passed through a 8 mm mesh sieve. The walls of the cup and the soil layer were sprayed with sufficient tap water for the soil not to become muddy. Plastic trays with plasticine were then placed into the center of each arena (Fig. 1). The experimental slugs were weighed to an 10^{-2} g accuracy, and one was put randomly into each of the experimental arenas. The cups were covered with a perforated plastic lid. The experimental animals were maintained at 16 h light : 8 h dark photoperiod and 25°C (unless indicated otherwise). The experiments started between 16:00–18:00 h, and lasted for 24 h (unless indicated otherwise). The slugs were then removed and the weight of plasticine consumed determined.

The determination of the relationship between slug body mass and plasticine consumption was carried out on June 8, 2005 (N = 25 individuals) and repeated on July 7, 2005 (N = 20). The experiment establishing the consumption of plasticine over ten days was made on July 19–29, 2005 (N = 20), and consumption was established twice, on July 24 (when the trays were replaced) and on July 29. The effect of alternative food was determined on July 20, 2005. The slugs were provided either with plasticine plus a piece of slug (*A. lusitanicus*) carcass (N = 15), or with plasticine plus a fresh leaf of each of seven broadleaved plants: *Aegopodium podagraria* L., *Bellis perennis* L., *Crepis biennis* L., *Geranium pratense* L., *Plantago major* L., *Taraxacum officinale* Weber ex Wiggers, and *Urtica dioica* L. (N = 15). All species of plants were common at the place where the slugs were collected. Intact leaves of these plants were collected just before the start of the experiment. The effects of temperature on consumption of plasticine was determined on September 6, 2005 (N = 12 at each temperature). The slugs were kept in climatised boxes at temperatures of 3, 6, 10, 15, 20, 25, or 30°C, which varied by ± 0.5°C. The dates are given because the experiments revealed that grazing activity may vary with the course of the season.

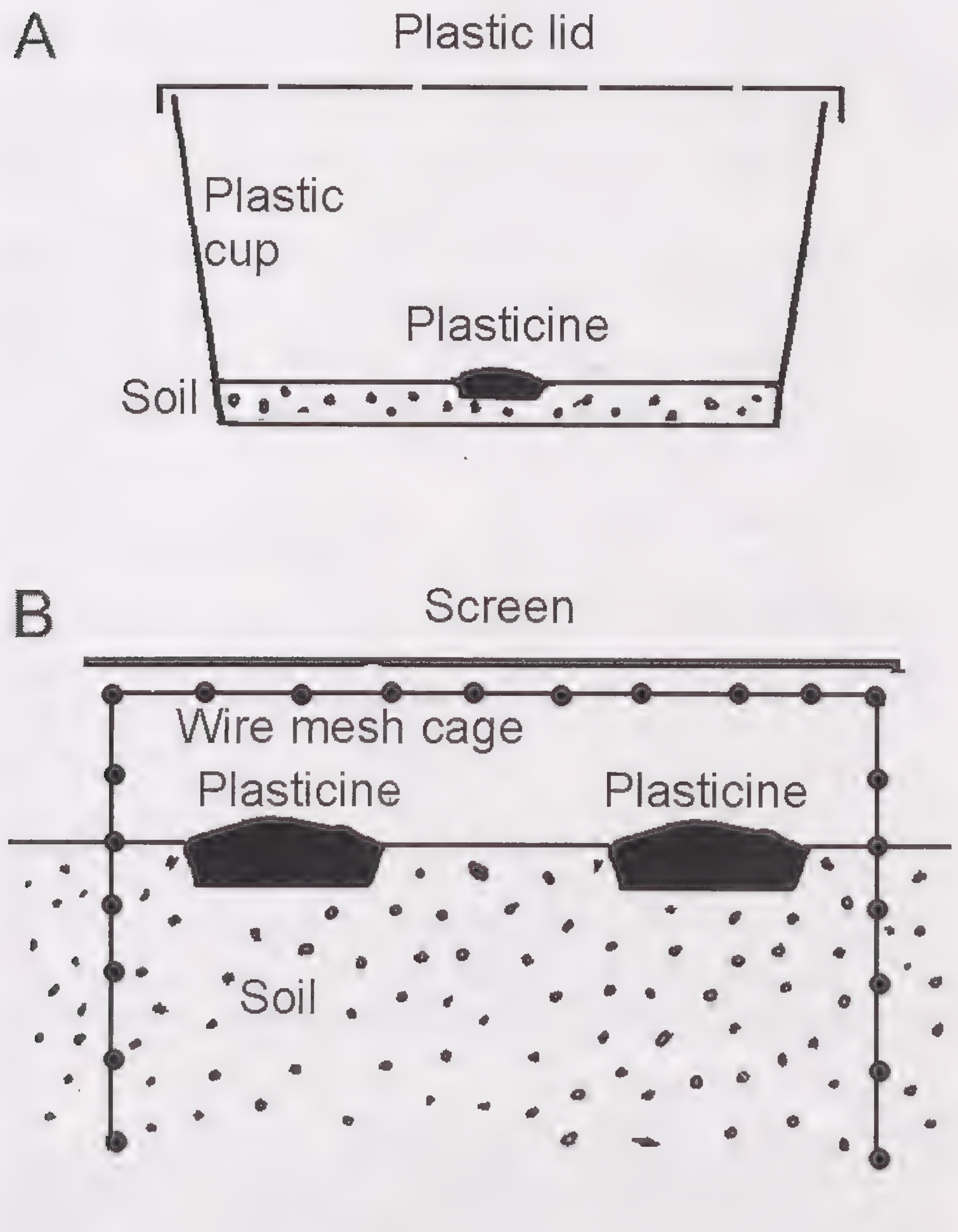

FIG. 1. Methods of exposing plasticine to slug grazing. A: In the laboratory; B: In the field. See Materials and Methods for detailed descriptions.

Field Experiments

Field experiments were made within the experimental area of the Research Institute of Crop Production at several sites, which differed in *A. lusitanicus* abundance. This large species was the dominant consumer of plasticine, because other large slugs (*Limax maximus* L., *Arion hortensis* s.l.) were rare, and small slugs (*Deroceras* sp.) only ate negligible amounts of plasticine. At each site, two tin trays filled with plasticine were placed in a 15 x 15 cm plot from which vegetation was removed and the soil loosened to a depth of approximately 10 cm. The trays were let into the soil so that plasticine surface was level with the soil surface. They were immediately covered with a roof-like cage of 10 x 10 cm area with 6 cm side walls, let into the soil to a depth of 4 cm. The cages were of 10 mm square mesh made of 1 mm thick wire (Fig. 1), which allowed access to slugs but prevented rodents from eating the plasticine.

In experiment (i) the relationship between slug abundance and plasticine consumption was established. On July 7, 2005, between 18:30–20:00 h, slugs were counted at 12 sites. At each site, slug numbers were established on ten plots of 0.25 m^2 size, randomly placed within an 6 x 6 m area centered around the place where the plasticine baits were placed. The slugs were counted by manually spreading the vegetation and counting all the visible individuals. Plasticine baits were put out on July 8–12, 2005. At each site, four cages were placed in the corners of a 1 x 1 m quadrat. In experiment (ii) the correlation between plasticine grazing activity in two successive periods, July 27–August 26, 2004, and August 26–September 17, 2004, was established. The cages were placed at eight sites, in the same arrangement as in experiment (i). In 2004, slugs were uncommon and grazing activity was so low that the plasticine did not have to be replaced within each of the experimental

TABLE 1. Consumption of plasticine by molluscs. Species, date of collection (2005), and consumption of plasticine (n = number of individuals that did (Yes) or did not (No) eat the plasticine.

			Consumption	
Species	Date	n	Yes	No
Agriolimacidae				
Deroceras agreste (Linnaeus, 1758)	12-July	7	7	
Deroceras reticulatum (O. F. Müller, 1774)	*	9	9	
Arionidae				
Arion circumscriptus Johnston, 1828	24-July	4	3	1
Arion hortensis s.l.	8-July	6	6	
Bradybaenidae				
Fruticicola fruticum (O. F. Müller, 1774)	14-July	9	9	
Clausiliidae				
Balea biplicata (Montagu, 1803)	26-July	9	2	7
Cochlodina laminata (Montagu, 1803)	26-July	27	27	
Macrogastra ventricosa (Draparnaud, 1801)	16-July	2		2
Cochlicopidae				
Cochlicopa lubrica (O. F. Müller, 1774)	26-July	11		11
Discidae				
Discus ruderatus (A. Férussac, 1821)	16-July	11	11	
Enidae				
Chondrula tridens (O. F. Müller, 1774)	8-July	3		3
Zebrina detrita (O. F. Müller, 1774)	14-July	1		1
Helicidae				
Arianta arbustorum (Linnaeus, 1758)	10-July	9	9	
Cepaea hortensis (O. F. Müller, 1774)	8-July	12	11	1
Cepaea nemoralis (Linnaeus, 1758)	8-July	6	6	
Cepaea vindobonensis (A. Férussac, 1821)	14-July	5	4	1
Helicigona lapicida (Linnaeus, 1758)	10-July	1	1	
Helix pomatia Linnaeus, 1758	5-July	8	7	1
Hygromiidae				
Monachoides incarnatus (O. F. Müller, 1774)	26-July	11	5	6
Trichia hispida (Linnaeus, 1758)	14-July	2		2
Urticicola umbrosus (Pfeiffer, 1828)	26-July	38	11	27
Xerolenta obvia (Menke, 1828)	7-July	6	6	
Limacidae				
Lehmania marginata (O. F. Müller, 1774)	16-July	5	1	4
Limax cinereoniger Wolf, 1803	16-July	2	2	
Limax maximus (Linnaeus, 1758)	26-July	4	4	
Malacolimax tenellus (O. F. Müller, 1774)	24-July	4	4	
Milacidae				
Tandonia rustica (Millet, 1843)	24-July	1	1	
Succineidae				
Succinea putris (Linnaeus, 1758)	26-July	8	7	1
Zonitidae				
Oxychilus cellarius (O. F. Müller, 1774)	26-July	8	2	6

periods. Experiment (iii) was done in 2003–2005. Each year, two cages were put out at a grassy site (high abundance of slugs) and a set-aside field (low abundance), from April 10 until October 31. The distance between the sites was 70 m. The trays were replaced weekly and at the time of maximum grazing activity in 2005, twice a week.

Grazing by Other Slugs and Snails

Plasticine was offered to another 29 common species of slugs and snails collected at several localities in western Czech Republic, between July 8–26, 2005 (Table 1). Species were identified according to Lozek (1956) and Kerney & Cameron (1999). If possible ≥ 5 individuals of each species was tested, except for rare species. They were collected in 0.5 l plastic bottles and within 24 h offered plasticine under the same conditions as in the laboratory experiments using *A. lusitanicus* (25°C, 16 h light : 8 h dark photoperiod). Plasticine was offered for one day except for those animals that did not readily eat the plasticine, when the period of exposure was extended to one week. The animals that scraped the surface of the plasticine were classified as "eating plasticine", those that did not as "not eating plasticine". If the molluscs were small and the presence of scrapes dubious, each individual was kept for 24 h in a 9 x 56 mm glass tube and its faeces examined. Eating plasticine resulted in the production of white faeces.

Data Processing

For the laboratory results, the correlation and linear regression of plasticine consumption on slug fresh body mass were calculated and the differences between slopes and intercepts of regression lines tested using Generalised Linear Models in R system, a free statistical product available at the Internet (R Development Core Team, 2004). The weight of plasticine consumed was standardized per unit *A. lusitanicus* mass. The differences in standardised consumption were tested using one-way ANOVA, with consumption in particular replicates as a response variable and treatment (slug age, alternative food, temperature) as factors. The differences between numbers of slugs eating plasticine at different temperatures were tested by chi-sqaure test. In the field, average plasticine consumption tray^{-1} over the experiment period was calculated for particular experiment sites (experiments i and ii). Consumption was regressed on slug numbers m^{-2} (experiment i), or consumption during one period was regressed on that in the other period (experiment ii). In experiment (iii), mean consumption day^{-1} trap^{-1} was calculated for each week or shorter period of exposure and plotted against time. Means (± SE) are given throughout the paper.

RESULTS

Laboratory Experiments

Plasticine consumption increased significantly ($p < 0.001$) and proportionately with the body mass of the slug, more so on June 8 than July 7 (Fig. 2). Average standardised consumption was also significantly ($p < 0.001$) higher earlier (0.082 ± 0.004 g . g slug body mass^{-1} . day^{-1}) than later in the year (0.039 ± 0.003 g . g slug body mass^{-1}. day^{-1}). Standardised consumption decreased as average slug body mass increased, from 1.53 ± 0.133 g on June 8 to 3.44 ± 0.445 g on July 7. Plasticine was consumed by all the slugs.

In the ten day no-choice experiment, plasticine was consumed by all experimental animals (n = 20), more on days 1–5 (0.012 ± 0.001 g . g slug body mass^{-1} . day^{-1}) than days 6–10 (0.005 ± 0.001 g . g slug body mass^{-1} . day^{-1}) of the experiment. The slugs thus gradually ceased eating plasticine, which they originally eagerly consumed. No slugs died during the ten-day experimental period, but they lost an average of 15.3 ± 2.0% of their original mass.

Providing alternative food influenced plasticine consumption. Only four of 15 experimental slugs (27%) provided with *A. lusitanicus* carcasses ate plasticine, and their consumption of plasticine (0.014 ± 0.006 g . g slug body mass^{-1} . day^{-1}) was significantly less (ANOVA: $F_{1,17}$ = 6.694, $p < 0.05$) than that of slugs offered leaves. All the experimental slugs eagerly consumed conspecific carcasses.When provided with leaves of seven broadleaved

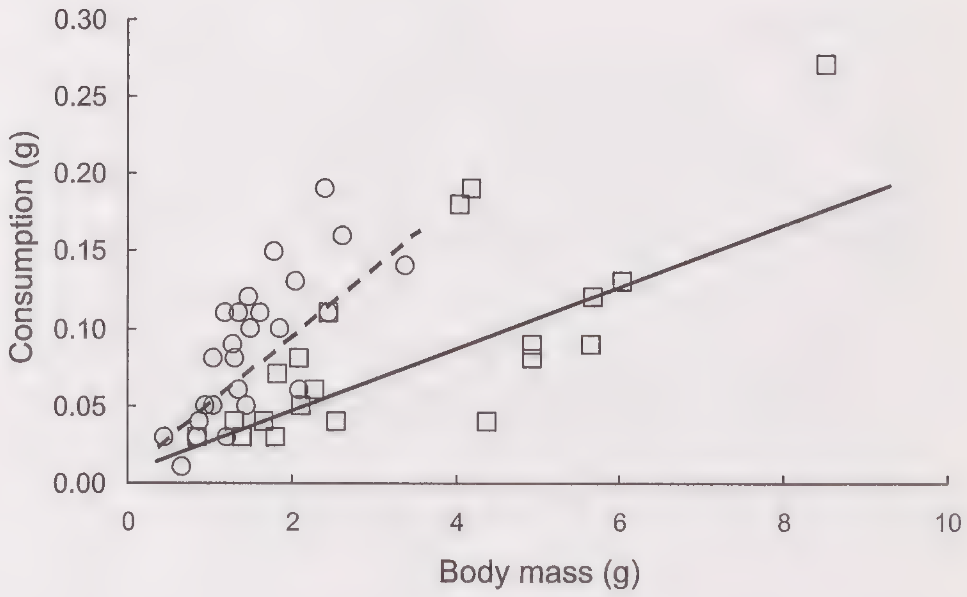

FIG. 2. The quantity of plasticine consumed vs. wet body mass of *A. lusitanicus*, established on June 8 (o , n = 25, a = 0.0517, b = 0.0084, $F_{1,23}$ = 30.64, $p < 0.001$) and July 7 (, n = 20, a = 0.0238, b = 0.0067, $F_{1,18}$ = 24.65, $p < 0.001$).

herbaceous plants, all experimental slugs (n = 15) ate plasticine (0.035 ± 0.004 g . g slug body mass^{-1} . day^{-1}). Plasticine was consumed despite herbivory: fourteen slugs nibbled at least one leaf. They preferred the leaves *A. podagraria* and *P. major* (both eaten by six individuals), *C. biennis* (five), followed by *T. officinale* (three) and *B. perennis* (two). Leaves of *G. pratense* and *U. dioica* were avoided. Plasticine consumption was similar to that recorded in the no-choice experiment of July 7, although the experimental slugs were heavier (4.62 ± 0.420 g).

Plasticine was eaten over a wide range of temperatures between 6–25°C (Fig. 3). The optimum temperature was 15°C, at which the proportion of slugs eating plasticine and the quantity eaten per individual was highest. The consumption decreased below and above 15°C. The numbers of slugs eating plasticine differed significantly (chi-square = 18.81, $p < 0.005$), but the standardised consumptions did not differ significantly (ANOVA: $F_{4,32} = 0.794$, NS). No consumption of plasticine was recorded at the lowest (3°C) and the highest (30°C) temperatures, probably because the change in slug behaviour.

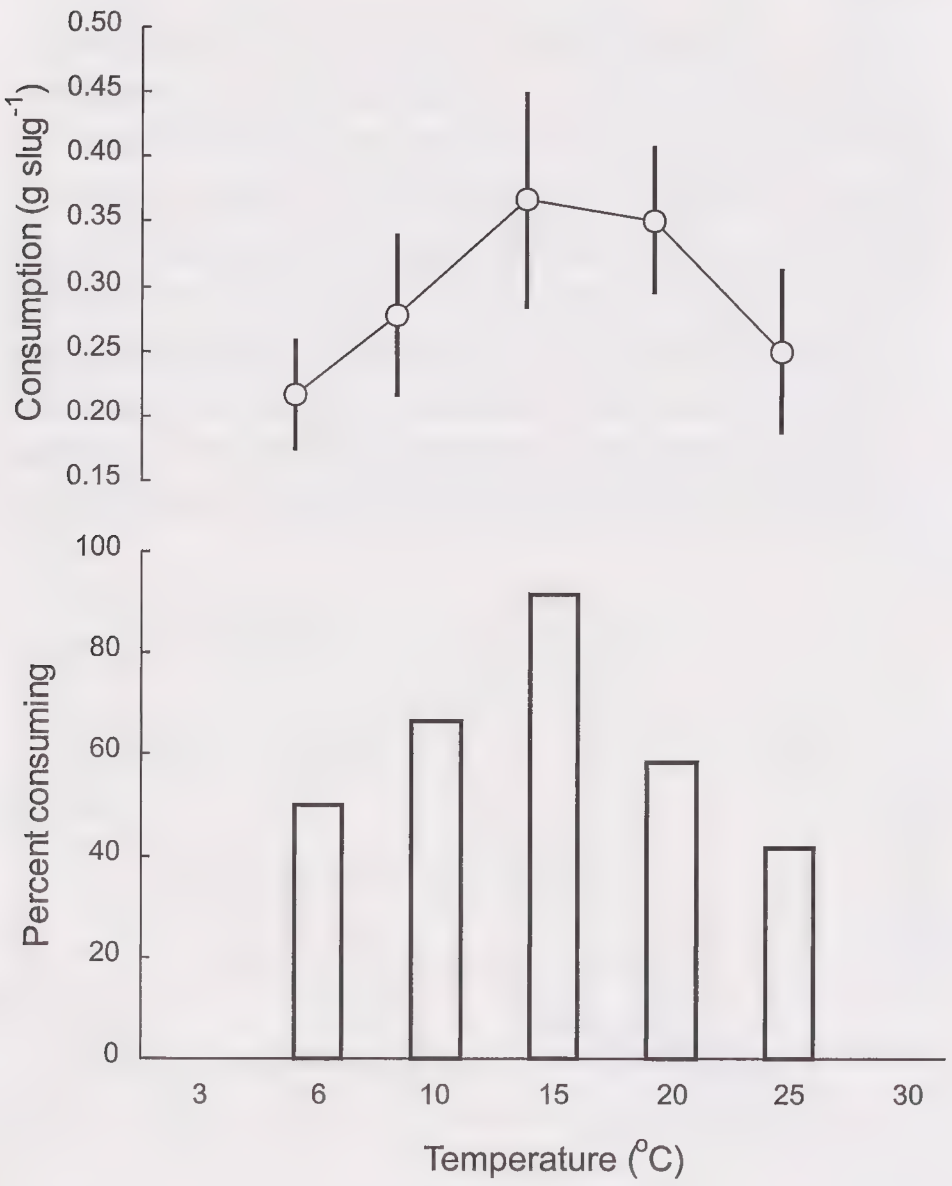

FIG. 3. The effect of different constant temperatures on plasticine consumption, September 6, 2005. Above: mean consumption slug^{-1} ± SE (calculated only for individuals that ate plasticine). Below: percentage of slugs eating plasticine (N = 12 at all temperatures). Plasticine was not eaten at 3 and 30°C.

Field Experiments

The average quantity of plasticine consumed over the four-day period (0.0–4.1 g tray^{-1}) differed significantly between the 12 sites (ANOVA: $F_{11,36} = 31.43$, $p < 0.001$) and significantly depended on slug abundance (Fig. 4). Average plasticine consumption at eight other sites was significantly correlated ($R^2 = 0.505$, $p < 0.05$) in the two successive periods, with a total duration was 52 days (Fig. 5). This revealed that the mosaic pattern of grazing activity persisted in time, which suggests that patterns of slug abundance are maintained through a season.

Seasonal variation in plasticine consumption was similar in 2003–2005 (Fig. 6). Grazing activity was in all years maximum in July and August and lower before and after this period. At the grassy site, peak consumption was approximately ten times greater in the year of high slug abundance (2005) than in previous years, when slug abundance was low. At the other site (set-aside field), the annual differences in plasticine grazing were similar, although the maximum consumption was approximately ten times lower than at the grassy site. There was virtually no feeding on plasticine in 2003 and 2004, while some consumption occurred in 2005, when some *A. lusitanicus* colonized the fallow from more favourable surrounding sites.

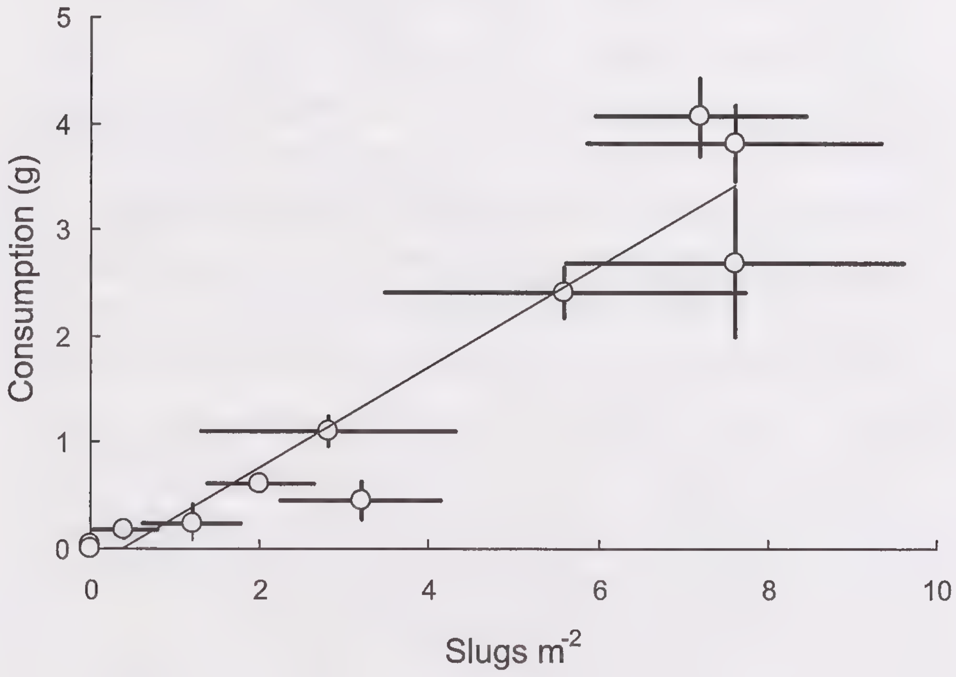

FIG. 4. Average plasticine consumption ± SE (g tray^{-1} eaten on July 8–12, 2005) vs. average numbers m^{-2} ± SE of *A. lusitanicus* (July 7, 2005), at 12 sites at Praha-Ruzyne (a = 0.4722, b = -0.1767, $F_{1,10} = 99.70$, $p < 0.001$).

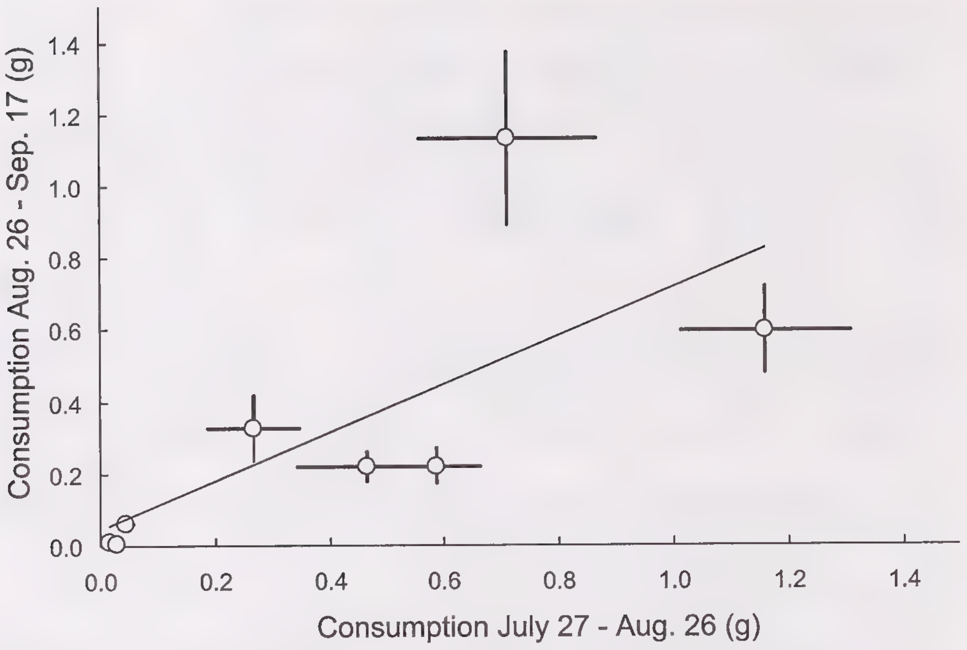

FIG. 5. Average plasticine consumption ± SE (g tray^{-1} period^{-1}) at eight sites at Praha-Ruzyne on Aug. 26–Sep. 17, 2004 vs. consumption on the same sites on July 27–Aug. 26, 2004 ($a = 0.6716$, $b = 0.0467$, $R^2 = 0.5053$, $p < 0.05$).

Grazing by Other Slugs and Snails

Laboratory testing of 29 species of slugs and snails (Table 1) revealed that *A. lusitanicus* is not the only species that eats plasticine. It was readily eaten by large snail species of the families Bradybaenidae and Helicidae, and all species of slug tested, except *L. marginata.* Mixed responses were obtained in the family Hygromiidae, in which *X. obvia* readily accepted plasticine, whereas other species were reluctant to eat it, or some individuals did and others did not eat. Few species were reluctant to eat plasticine, mostly small (*C. lubrica*, *O. cellarius*) and medium sized (*C. tridens*, *Z. detrita*) snails.

DISCUSSION

The results revealed that determining slug grazing by means of plasticine baits is a useful tool for establishing the grazing activity and abundance of *A. lusitanicus*. Laboratory experiments revealed the limitations of this method. The most important factor decreasing plasticine consumption was the presence of alternative food. Because of marked cannibalism in *A. lusitanicus*, dead conspecifics were more attractive than plasticine baits and significantly decreased the consumption of plasticine. Many *A. lusitanicus* are often killed on roads by traffic, and near such "carnage" feeding on plasticine may be confounded by cannibalism. Moreover, *A. lusitanicus* is attracted by baits of vertebrate meat (Z. Martinkova, unpubl.) and presence of an animal carcass may have the same local effect as dead slugs. By contrast, although *A. lusitanicus* eat many species of plants (Briner & Frank, 1998b; Keller et al., 1999), the presence of preferred species, for example, *A. podagraria* (Kozlowski & Kozlowska, 2000), did not reduce the consumption of plasticine.

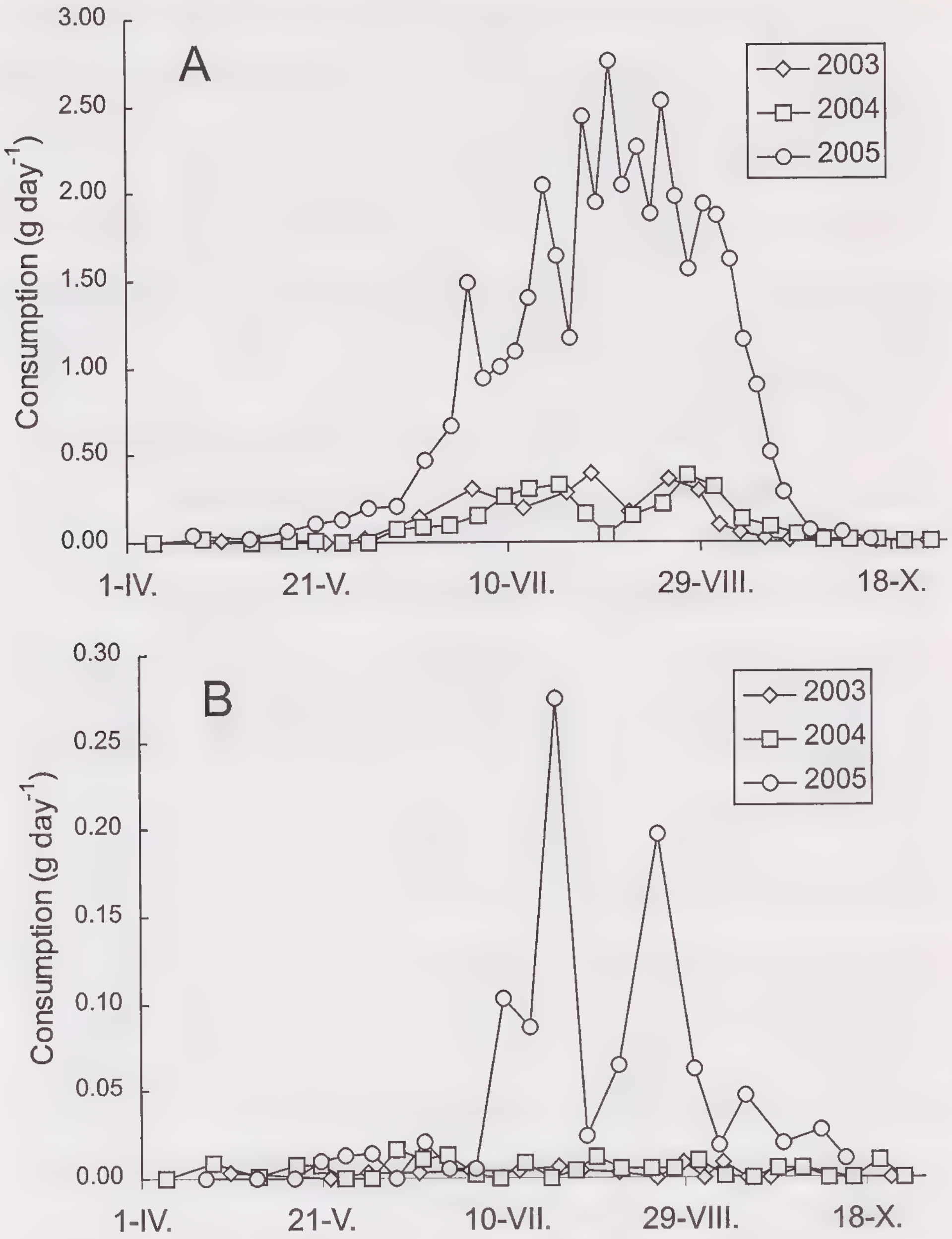

FIG. 6. Consumption of plasticine (g tray^{-1} day^{-1}) through the vegetative season (April–October) 2003–2005. A: Grassy plot; B: Set-aside field, at Praha-Ruzyne. Note different scales on ordinates.

Plasticine was eaten over a wide range of temperatures, and feeding ceased only at low (3°C) and high (30°C) temperatures. At intermediate temperatures, there was a variation in the proportion of individuals eating plasticine and in the amount consumed per individual, with a maximum at 15°C. In our experiment, this variation was probably apparent because consumption was measured late in the season, on September 6, when feeding activity of field collected animals was low (Fig. 6). In June–August, when it was at a maximum, slugs might be less affected by differences in temperature. This was apparent in the laboratory experiments made in June and July, at room temperature of 25°C, when slugs feed the plasticine well. Tolerance of a wide range of temperatures is probably an essential feature of *A. lusitanicus* and enables this species to remain active over a large part of the day, except for the warmest period in the early afternoon (Grimm et al., 2000). Quality of plasticine (viscosity and/or release of volatiles) also might have change at the upper and lower temperatures.

The experiments in the field revealed spatial variation in *A. lusitanicus* grazing. This local variation in plasticine consumption persisted within a season but may differ between years. The changes were due to annual variations in overall slug abundance that resulted in some places only being colonized in years when slugs were abundant. The changes may be inferred from reports of pest occurrences involving *A. lusitanicus* registered by the national Phytomedicine Survey. They were uncommon in 2003 and 2004, but increased sharply in abundance in 2005 (J. Rehak, personal communication). In our experiments, this change resulted in, for example, a change in grazing activity revealed in the set-aside field, where there was no grazing in 2003 and 2004, but plasticine was consumed in 2005. Direct observation of the plasticine baits revealed that other slug species, particularly *D. reticulatum*, contributed to grazing activity late in the season (October–November), when *A. lusitanicus* was already absent. However, because grazing activity at this period was low compared to July–August (Fig. 6), the contribution of species other than *A. lusitanicus* to overall grazing was very small.

Determining slug numbers from plasticine grazing appears at first sight to be difficult. Although consumption of plasticine in the laboratory was proportional to slug mass, the relationship was weak and the consumption per unit body mass changed during the course of the season. Moreover, the small home ranges of *A. lusitanicus* (Grimm & Paill, 2001) might prevent random access of individuals to plasticine baits. Despite these confounding factors, plasticine grazing was a good indicator of *A. lusitanicus* numbers at particular sites.

What are the advantages of plasticine baits compared to the other methods of establishing the presence of slugs in the field? The most frequently used methods are direct sampling (Frank, 1998d), establishing enclosures (Theenhaus & Schaefer, 1999), flooding samples slowly submerging them in water (Bohan et al., 2000), washing snails over sieves (Iglesias et al., 2001), seting traps of cardboard (Grimm & Paill, 2001) or other materials (Hanley et al., 1996; Scheidel & Bruelheide, 2001), and exposing baits consisting of preferred food (Frank, 1998c). These methods can be calibrated to reveal slug abundance but not grazing activity. The use of plasticine bait in the field thus appears to be a convenient new method for establishing slug grazing activity and has already proved useful in studies of weed seedling mortalitiy due to *A. lusitanicus* (A. Honek, Z. Martinkova & P. Saska unpubl.).

Plasticine baits might be useful also for studies on the grazing activity of other slugs. For small species of Agriolimacidae, however, the method of exposure in the field should be modified, because they consume very little, which is difficult to establish by weighing. Feeding marks on the surface of the plasticine probably could be evaluated optically. However, the method cannot be used for investigating snail activity, perhaps with the exception of small species, like *X. obvia*. This is because plasticine is readily consumed by mice and therefore should be surrounded by cages of wire mesh with maximum approximately 1 cm wide openings. Our observations indicate (A. Honek & Z. Martinkova unpubl.) that this mesh size permits access of even the largest specimens of *A. lusitanicus*, approximately 12 cm long. However, access of large snails is prevented because of their shell size.

ACKNOWLEDGEMENTS

We thank Prof. A. F. G. Dixon for valuable comments and improving the English, and Mrs. L. Kreslova and Mrs. H. Uhlirova for excellent technical assistance. The work was supported by grant no. QG 50107 of the National Agency for Agricultural Research of the Ministry of Agriculture of the Czech Republic.

LITERATURE CITED

BARTA, R., 1934, Plastilina [Plasticine]. P. 291, in: V. TEYSSLER & V. KOTYSKA, eds., *Technicky slovnik naucny Dil X* [*Technical encyclopaedia Vol. X*], Borsky a Sulc, Praha.

BOHAN, D. A., D. M. GLEN, C. W. WILTSHIRE & L. HUGHES, 2000, Parametric intensity and the spatial arrangement of the terrestrial mollusc herbivores *Deroceras reticulatum* and *Arion intermedius*. *Journal of Animal Ecology*, 69: 1031–1046.

BRINER, T. & T. FRANK, 1998a, Egg laying activity of the slug *Arion lusitanicus* Mabille in Switzerland. *Journal of Conchology*, 36: 9–15.

BRINER, T. & T. FRANK, 1998b, The palatability of 78 wildflower strip plants to the slug *Arion lusitanicus*. *Annals of Applied Biology*, 133: 123–133.

BRUELHEIDE, H. & U. SCHEIDEL, 1999, Slug herbivory as a limiting factor for the geographical range of *Arnica montana*. *Journal of Ecology*, 87: 398–848.

BUSCHMANN, H., M. KELLER, N. PORRET, H. DIETZ & J. P. EDWARDS, 2005, The effect of slug grazing on vegetation development and plant species diversity in an experimental grassland. *Functional Ecology*, 19: 291–298.

COOK, R. T., S. E. R. BAILEY & C. R. MCCROHAN, 1997, The potential for common weeds to reduce slug damage to winter wheat: laboratory and field studies. *Journal of Applied Ecology*, 34: 79–87.

FISCHER, W. & P. L. REISCHUTZ, 1998, General aspects about the slugpests. *Bodenkultur*, 49: 281–292.

FRANK, T., 1998a, Slug damage and number of slugs (Gastropoda : Pulmonata) in winter wheat in fields with sown wildflower strips. *Journal of Molluscan Studies*, 64: 319–328.

FRANK, T., 1998b, Slug damage and numbers of slugs in oilseed rape bordering on grass strips. *Journal of Molluscan Studies*, 64: 461–465.

FRANK, T., 1998c, Slug damage and numbers of the slug pests, *Arion lusitanicus* and *Deroceras reticulatum*, in oilseed rape grown beside sown wildflower strips. *Agriculture Ecosystems and Environment*, 67: 67–78.

FRANK, T., 1998d, The role of different slug species in damage to oilseed rape bordering on sown wildflower strips. *Annals of Applied Biology*, 133: 483–493.

FRANK, T., 2003, Influence of slug herbivory on the vegetation development in an experimental wildflower strip. *Basic and Applied Ecology*, 4: 139–147.

GLEN, D. M. & R. MOENS, 2002, Agriolimacidae, Arionidae and Milacidae as pests in West European cereals. Pp. 271–300, in: G. M. BARKER, ed., *Molluscs as crop pests*. CABI Publishing, Wallingford. xii + 468 pp.

GRIMM, B., 2001, Life cycle and population density of the pest slug *Arion lusitanicus* Mabille (Mollusca : Pulmonata) on grassland. *Malacologia*, 43: 25–32.

GRIMM, B. & W. PAILL, 2001, Spatial distribution and home-range of the pest slug *Arion lusitanicus* (Mollusca : Pulmonata). *Acta Oecologica*, 22: 219–227.

GRIMM, B., W. PAILL & H. KAISER, 2000, Daily activity of the pest slug *Arion lusitanicus* Mabille. *Journal of Molluscan Studies*, 66: 125–128.

HANLEY, M. E., M. FENNER & P. J. EDWARDS, 1996, Mollusc grazing and seedling survivorship of four common grassland plant species: the role of gap size, species and season. *Acta Oecologica*, 17: 331–341.

HOMMAY, G., O. LORVELEC & F. JACKY, 1998, Daily activity rhythm and use of shelter in the slugs *Deroceras reticulatum* and *Arion distinctus* under laboratory conditions. *Annals of Applied Biology*, 132: 167–185.

HONEK, A., Z. MARTINKOVA & V. JAROSIK, 2003, Ground beetles (Carabidae) as seed predators. *European Journal of Entomology*, 100: 531–544.

HONEK, A., Z. MARTINKOVA & P. SASKA, 2005, Post-dispersal predation in *Taraxacum officinale* (dandelion) seed. *Journal of Ecology*, 93: 345–352.

HORSAK, M. & L. DVORAK, 2003, Co vime o plzaku spanelskem (*Arion lusitanicus*) [What we know about *Arion lusitanicus*]. Pp. 35–36, in: J. BRYJA & J. ZUKAL, eds., *Zoologicke dny Brno 2003. Sbornik abstraktu z konference 13–14 unora 2003*. Ustav Biologie Obratlovcu AVCR, Brno. 244 pp.

IGLESIAS, J., J. CASTILLEJO & R. CASTRO, 2001, Mini-plot field experiments on slug control using biological and chemical control agents. *Annals of Applied Biology*, 139: 285–292.

KELLER, M., J. KOLLMANN & P. J. EDWARDS, 1999, Palatability of weeds from different European origins to the slugs *Deroceras reticulatum* Muller and *Arion lusitanicus* Mabille. *Acta Oecologica*, 20: 109–118.

KERNEY, M. P. & R. A. D. CAMERON, 1999, *Escargots et limaces d´Europe*. Delchaux et Niestlé, Lausanne, Paris. 370 pp.

KOZLOWSKI, J. & M. KOZLOWSKA, 2000, Weeds as a supplementary or alternative food for *Arion lusitanicus* Mabille (Gastropoda : Stylommatophora). *Journal of Conchology*, 37: 75–79.

LOZEK, V., 1956, *Klic Ceskoslovenskych Mekkysu* [*Key of Czechoslovak Mollusca*]. Vydavatelstvo Slovenskej Akademie Vied, Bratislava. 437 pp., 42 pls.

MOENS, R. & D. M. GLEN, 2002, Agriolimacidae, Arionidae and Milacidae as pests in West European oilseed rape. Pp. 425–439, in: G. M. BARKER, ed., *Molluscs as crop pests*. CABI Publishing, Wallingford. xii + 468 pp.

R DEVELOPMENT CORE TEAM, 2004, R: A language and environment for statistical computing. R Foundation for Statistical Computing Vienna, Austria. Available at http://www.R-project.org

SCHEIDEL, U. & H. BRUELHEIDE, 2001, Altitudinal differences in herbivory on montane Compositae species. *Oecologia*, 129: 75–86.

THEENHAUS, A. & M. SCHAEFER, 1999, Energetics of the red slug *Arion rufus* (Gastropoda) and of the gastropod community in a beech forest on limestone. *Malacologia*, 41: 197–208.

Revised ms. accepted 29 September 2006